U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

6.5.4 ICE CONDENSER AS A FISSION PRODUCT CLEANUP SYSTEM

REVIEW RESPONSIBILITIES

Primary - Chemical Engineering Branch

Secondary - Plant Systems Branch
Radiation Protection Branch

I. AREAS OF REVIEW

The ice condenser system is reviewed to determine the fission product removal effectiveness whenever the applicant claims a containment atmosphere fission product cleanup function for the system.

The following areas of the applicant's safety analysis report (SAR) are reviewed:

1. Fission Product Removal Requirement for the Ice Condenser System

   Sections of the SAR related to accident analyses, dose calculations, and fission product removal and control are reviewed to establish whether or not fission product scrubbing of the containment atmosphere is required for mitigation of radiological consequences following a postulated accident. This review usually covers SAR Chapters 6 and 15.

2. Design Bases

   The design bases for the fission product removal function of the ice condenser system are reviewed to verify that they are consistent with the assumptions made in the accident evaluations of SAR Chapter 15.

The methodology used in this SRP section is not intended for containment venting evaluation. Containment venting will be considered in the evaluation of ice condensers as fission product cleanup systems when the Commission approves the final guidance on containment venting.

3. System Design

The information on the design of the ice condenser system important to its fission product removal function is reviewed to familiarize the reviewer with the design and post-accident functioning of the ice condenser. The information includes:

a. The basic design concept, the systems, subsystems, and support systems required to carry out the fission product cleanup function of the ice condenser.

b. Descriptions and figures from the SAR related to the time required to establish a steady flow of an air-steam-iodine mixture through the ice beds, and the time of meltout of the ice beds.

4. Testing and Inspections

The details of the applicant's proposed preoperational test to be performed for system verification and operational tests and inspections to verify the continued status of readiness of the iodine removal capacity of the ice condenser system are reviewed.

5. Technical Specifications

At the operating license stage, the applicant's proposed technical specifications are reviewed to establish surveillance requirements for the proposed chemical additive concentrations in the ice.

The pressure suppression function of the system is reviewed under SRP Sections 6.2.1 and 6.2.1.1.B.

II. ACCEPTANCE CRITERIA

The acceptance criteria for the fission product cleanup function of the ice condenser system are based on the relevant requirements of the following regulations:

A. General Design Criterion 41 (Ref. 1) as it relates to containment atmosphere cleanup systems being designed to control fission products that may be released to the reactor containment following postulated accidents.

B. General Design Criterion 42 (Ref. 2) as it relates to containment atmosphere cleanup systems being designed to permit appropriate periodic inspections.

C. General Design Criterion 43 (Ref. 3) as it relates to containment atmosphere cleanup systems being designed to permit appropriate periodic functional testing.

Specific criteria necessary to meet the relevant requirements of General Design Criteria 41, 42, and 43 include:

1. The ice condenser system is acceptable for elemental iodine removal if the ice contains a quantity of the proposed chemical additive sufficient to ensure that the pH of the post-accident recirculating solution is above 7 (Ref. 4).

2. The technical specifications are acceptable if they specify appropriate limiting conditions for operations, tests, and inspections to ensure that the system is capable of its design function whenever the reactor is critical. These specifications should include: the operability requirements for the system, and periodic sampling and testing requirements of the ice to confirm that the concentration of the chemical additive in the ice melt is within the limits established by the system design.

While granting credit for ice condenser scrubbing of fission products in the calculations of accident doses, the acceptance criteria of containment leakage in SRP Section 6.2.1.1.B and the acceptance criteria of the engineered safety feature atmosphere cleanup systems in SRP Section 6.5.1 should still be met.

III. REVIEW PROCEDURES

The reviewer selects and emphasizes specific aspects of this SRP section as are appropriate for a particular plant. The judgment on which areas need to be given attention and emphasis in the review is based on a determination of whether the material presented is similar to that recently reviewed on other plants and whether items of special safety significance are involved.

The first step in the review of the fission product removal function of the ice condenser system is to determine whether the ice condenser system is used for mitigating radiological consequences. Based on the information in Chapter 15 of the SAR, the reviewer determines whether a dose reduction credit was assumed for the ice condenser. If no fission product removal credit is assumed in the accident analysis, no further review is required under this SRP section.

If the ice condenser system is used for iodine removal, the iodine removal effectiveness of the ice condenser system is reviewed. The review includes the following:

1. System Design and Evaluation

   a. Chemical Additive

      To achieve long-term iodine retention, chemical compounds are usually added to the ice for adjusting the pH of the post-accident recirculating fluid when the ice melt is diluted and mixed with the containment sump solution, primary coolant, emergency core cooling system water, and containment spray solution, if any.

Long-term retention of iodine may be assumed only when the recirculating fluid meets the pH range specified in the acceptance criteria of this SRP section. For ice condenser systems similar to those of the D. C. Cook and Sequoyah plants (with a steady-state flow rate of approximately 40,000 cfm), an efficiency of 30% per pass for elemental iodine is assigned. The system is considered ineffective for organic iodide and particulate iodine removal. For designs different from those of D. C. Cook and Sequoyah plants, reconsideration of the system efficiency is required. The reviewer should consult References 5, 6, and 7 when evaluating the iodine removal efficiency of the ice condenser. Reference 6, in particular, should be considered if time-dependent removal efficiencies are used. Reference 8 provides useful background information. Removal efficiencies of time-varying air-steam mixtures or flow rates should conservatively account for factors that affect their time dependencies (e.g., fan capacity, fan activation time, natural circulation rates).

b. Iodine Scrubbing Function

It is not feasible to specify the exact time of the fission product release following a postulated loss-of-coolant accident. In addition, the flow rates and air-steam fractions of the flow through the ice condenser vary significantly during and immediately following the accident. For radiological dose calculations, therefore, the following conservative assumptions are made:

(1) If a 30% iodine removal efficiency is used, the iodine removal effectiveness of the ice condenser commences with the establishment of a steady-state air-steam flow. Steady flow is assumed to start with the operation of the post-accident mixing fans. A single failure of one of the fans is assumed.

(2) The initial concentration of iodine is assumed uniform throughout the entire containment.

(3) The effectiveness of the ice condenser as an iodine removal system is assumed to cease with the meltout of the first ice bed.

c. Upper Compartment Spray Credit

Plants designed with an upper compartment spray system may claim credit for such. Containment spray systems are reviewed under SRP Section 6.5.2.

d. Evaluation

The iodine removal effectiveness and the degree of iodine dose mitigation by the ice condenser for the loss-of-coolant accident are determined using the air-steam fan flow rate and the assumptions in Subsections III.1.a and III.1.b.

2. Technical Specifications

The technical specifications are reviewed to assure that they require periodic inspections and sampling of the ice in order to confirm the continued state of readiness of the system, i.e., the system meets the chemistry requirements specified in the acceptance criteria of this SRP section.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided by the applicant and that the review and calculations support conclusions of the following type, to be included in the staff's safety evaluation report:

The staff has reviewed the fission product scrubbing function of the ice condenser and finds that the ice will reduce the elemental iodine concentration of the steam-air mixture flowing through the ice beds following a loss-of-coolant accident. The staff estimates an elemental iodine removal efficiency of ___% per pass during the time period starting at ___ minutes after the accident and ending at ___ minutes. The concept upon which the proposed system is based has been demonstrated to be effective for iodine sorption and retention under post-accident conditions. The system is largely passive in nature, but the active components are suitably redundant so that its safety function can be accomplished assuming a single failure. The applicant's proposed program for preoperational and periodic surveillance tests will ensure a continued state of readiness for the iodine removal function of the ice condenser system.

The staff concludes that the ice condenser as a fission product cleanup system is acceptable and meets the requirements of General Design Criterion 41 with respect to the iodine removal function following a postulated loss-of-coolant accident, General Design Criterion 42 with respect to the capability for periodic inspection of the system, and General Design Criterion 43 with respect to the capability for periodic testing of the system.

V. IMPLEMENTATION

The following guidance is provided to applicants and licensees about the staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation of the acceptance criteria in subsection II and the review procedures in subsection III is as follows:

1. Operating plants and applicants for operating licenses pending at the date of issue of this revision need not comply with the provisions of this revision, but may do so voluntarily.

2. Future applicants will be reviewed according to the provisions of this revision.

VI. REFERENCES

1. 10 CFR Part 50, Appendix A, General Design Criterion 41, "Containment Atmosphere Cleanup."

2. 10 CFR Part 50, Appendix A, General Design Criterion 42, "Inspection of Containment Atmosphere Cleanup Systems."

3. 10 CFR Part 50, Appendix A, General Design Criterion 43, "Testing of Containment Atmosphere Cleanup Systems."

4. C. C. Lin, "Chemical Effects of Gamma Radiation on Iodine in Aqueous Solutions," Journal of Inorganic and Nuclear Chemistry, 42, pages 1101-1107 (1980).

5. D. D. Malinowski and L. F. Picone, "Iodine Removal in the Ice Condenser System," Nuclear Technology, 10(4), pages 428-435 (1971).

6. Ice Condenser Containment Model; memo from R. Zavadoski to files, U.S. Atomic Energy Commission, June 19, 1972.

7. Review of Topical Report WCAP-7426; memo from H. R. Denton to R. C. DeYoung, U.S. Atomic Energy Commission, November 24, 1972.

8. R. A. Soldano, "Basic Properties of Ice as Related to the Performance of Ice Condensers", U.S. Atomic Energy Commission Report, WASH-1232, September 1972.